Solar and Heliospheric Physics for ILWS/CAWSES

Takeo Kosugi (ISAS/JAXA, Japan)

* *Why do we need study the Sun?*

1. **"The Sun as a Star"** (A Classical Field of Astrophysics)
   - Stellar Structure / Evolution
   - Dynamo Mechanism (Cosmic Magnetism)

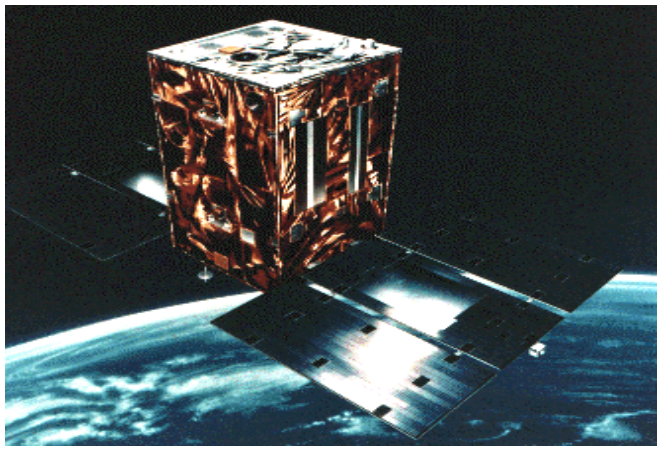
2. Corona: a Prototype for **Superhot Astrophysical Plasma**
   - Why is the corona so hot?
   - Coronal Structure / Dynamics
   - Sudden Energy Release and Particle Acceleration

   * **Key Word: Magnetic Reconnection**

3. Factors Controlling the **Space Weather and Climate**
   - Solar Wind
   - Flares and CMEs as a Cause of IP Disturbances

Golden Age of Solar Physics from Space

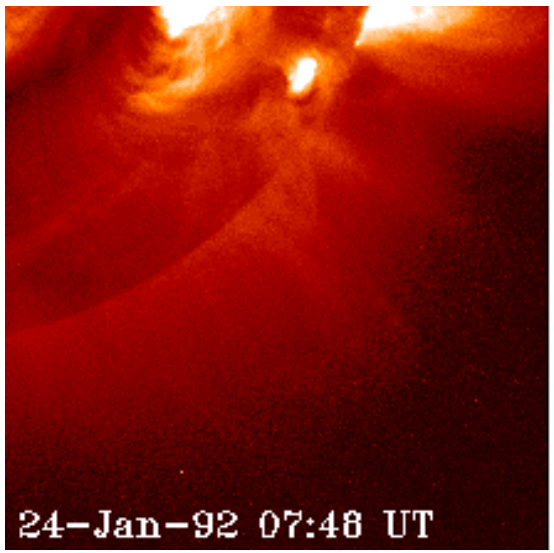
- **Yohkoh (1991 - 2001) Japan / US / UK**
  - **Hard and Soft X-ray Imaging;**
  - **X-ray & Gamma-ray Spectroscopy; Flares**
- **SoHO (1996 -) ESA / NASA**
  - **Solar & Heliospheric Imaging; Helio-seismology**
- **TRACE (1998 -) NASA;**
  - **Highest Spatial Resolution UV & EUV Imaging**
- **CORONAS-F (2001 -) RSA**
  - **Coronal Imaging and Spectroscopy**
- **RHESSI (2002 -) NASA / other**
  - **High-Energy Solar Spectroscopic Imager; Flares**
- **CGRO, Ulysses, and other heliospheric missions**

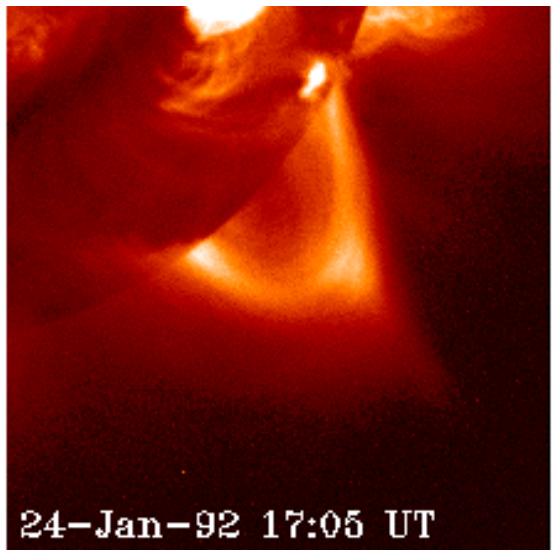


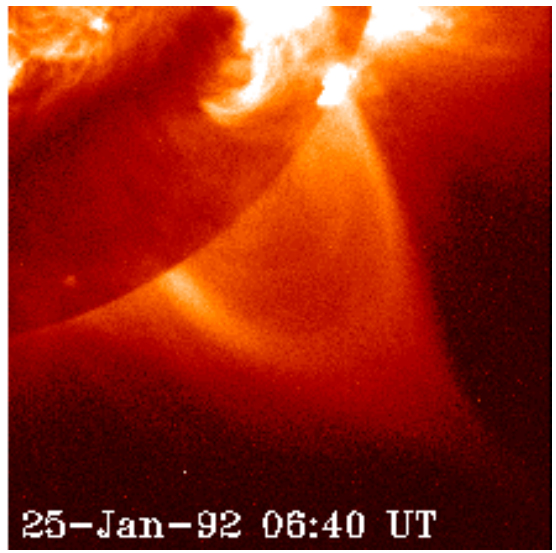
Ten Years with *Yohkoh*

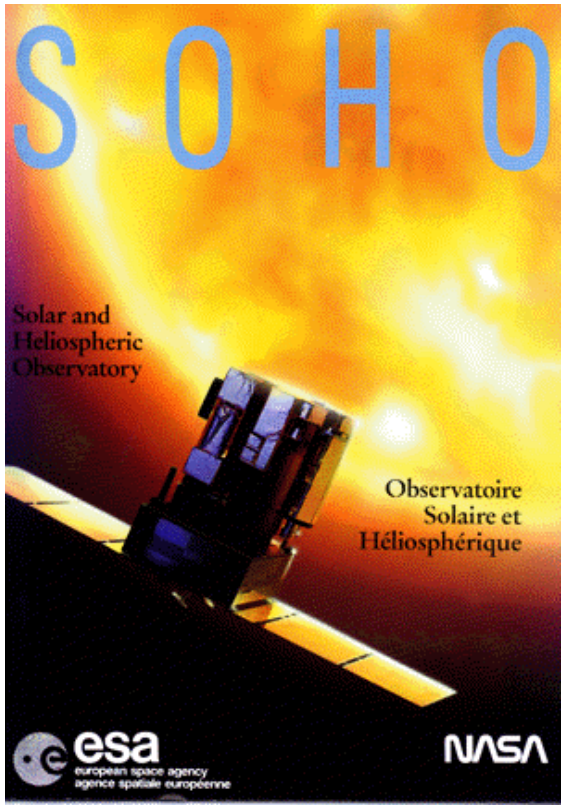
(1991 September – 2001 December)

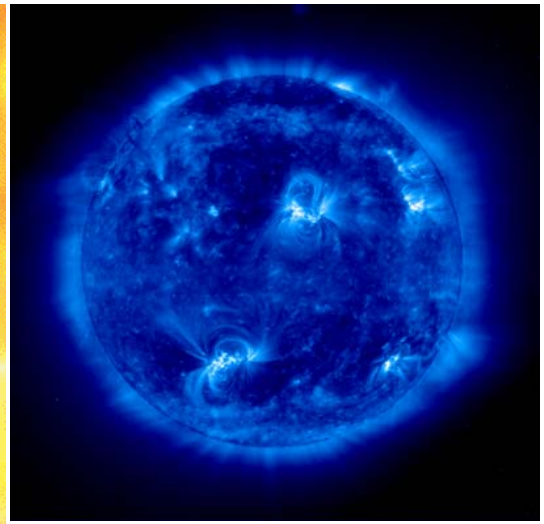
Energy Release and Particle Acceleration in the Solar Atmosphere







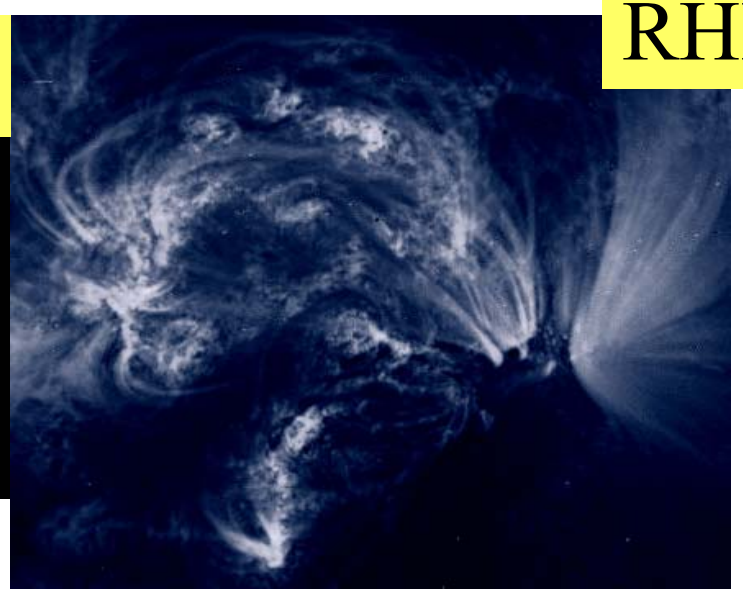




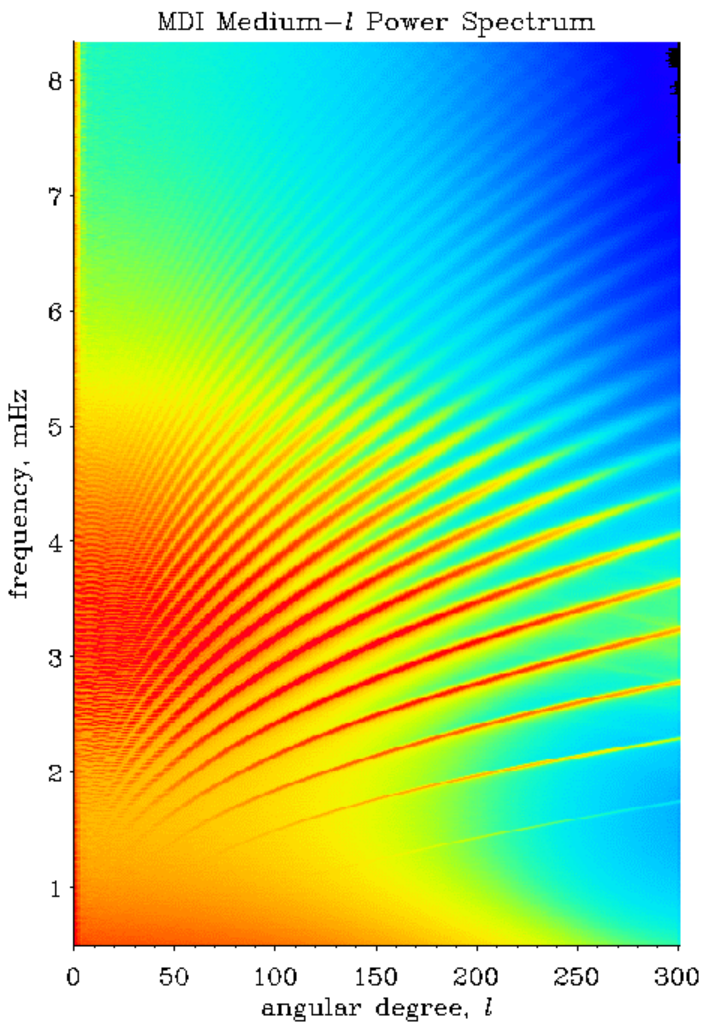
← SoHO (96 -)

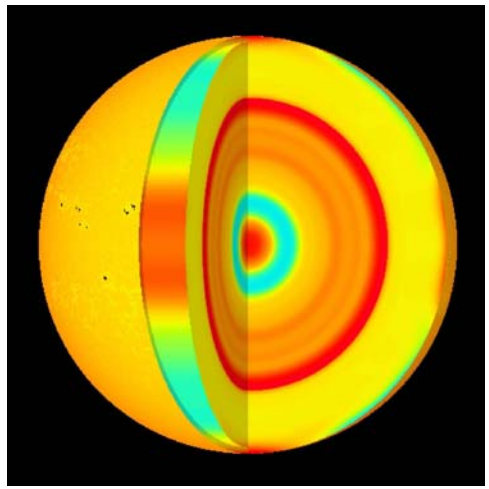
RHESSI (02 -)

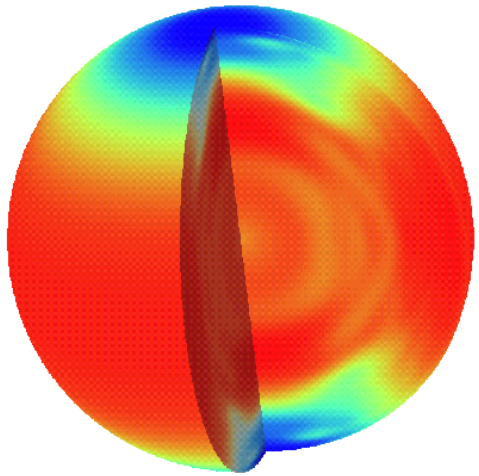
TRACE (98 -)

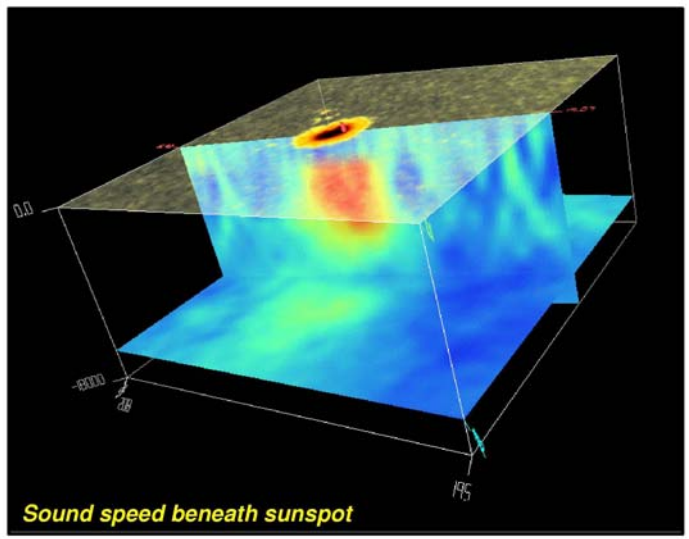


Understanding the Solar Interior:
-- Helioseismology by SoHO --





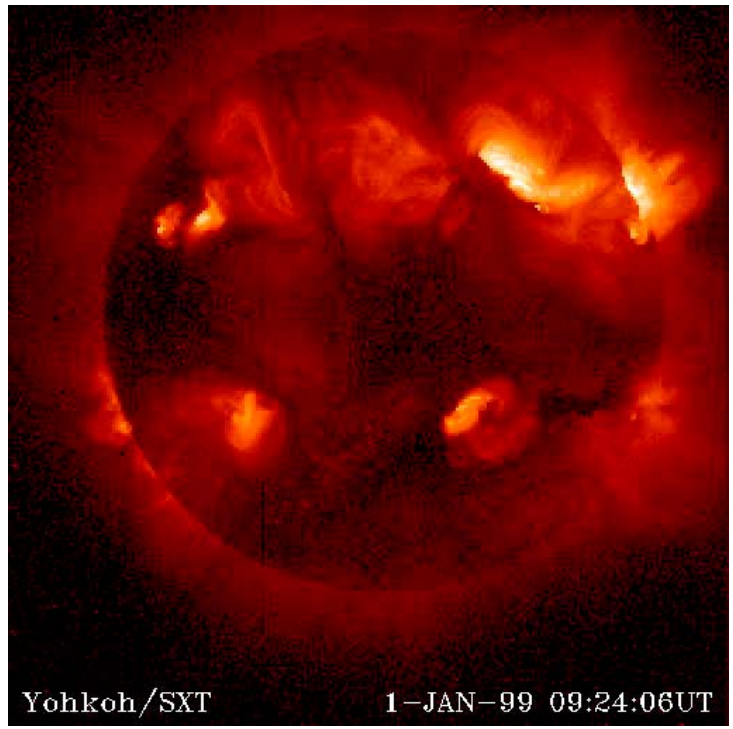




Sunspot data from MDI High Resolution, 18 June 1998

The Solar Atmosphere

Various structures and dynamics, governed by magnetic fields

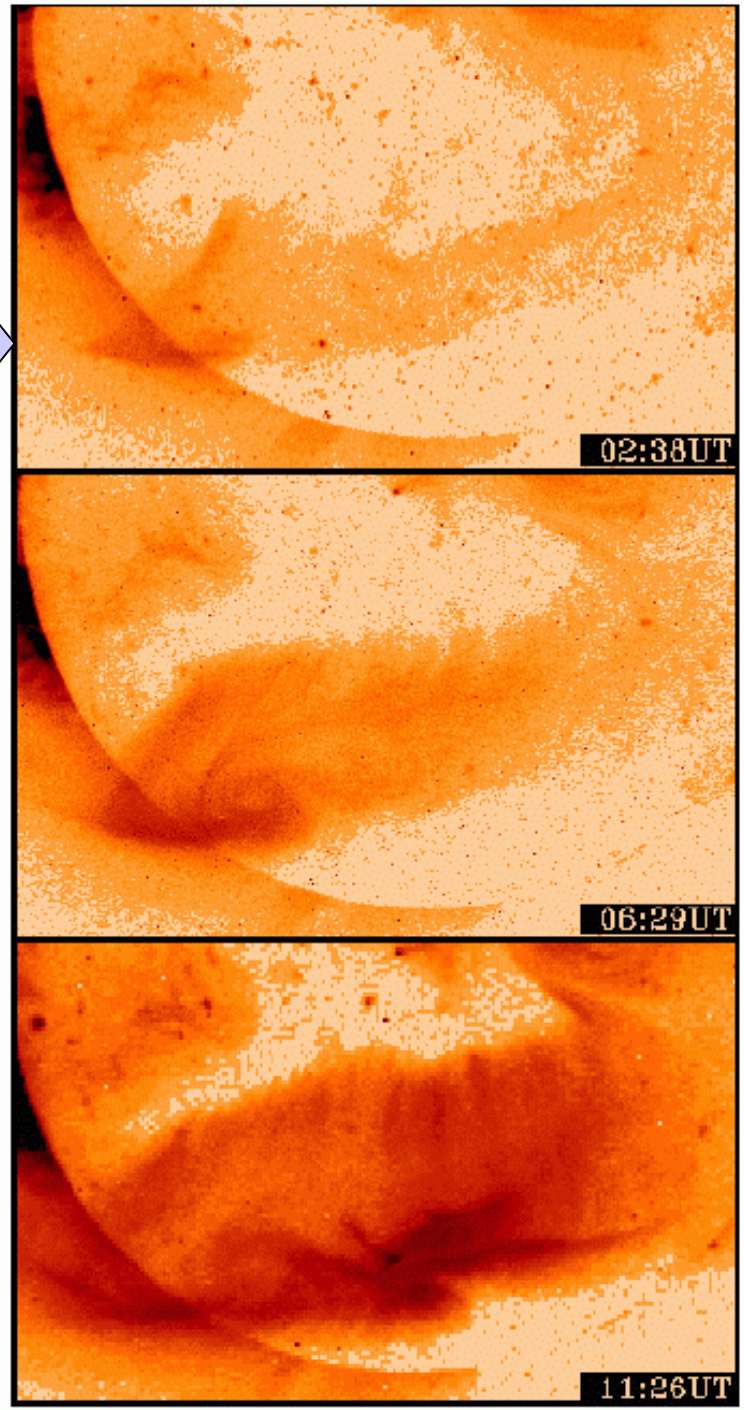


- **Coronal heating**
  - **11-yr cycle variation**
- **Ejections and IP disturbances**
  - **Large-scale restructuring**
  - **X-ray plasmoid**
  - **X-ray dimming (vs CME)**
  - **X-ray sigmoid (vs CME)**
- **Solar flares as magnetic reconnection process**
  - **Soft X-ray loop-with-a-cusp structure, increasing in size with time**
  - **Double-footpoint plus above-a-loop-top hard X-ray sources**
  - **Particle acceleration site in the above-a-loop-top hard X-ray source**
  - **X-ray jets**

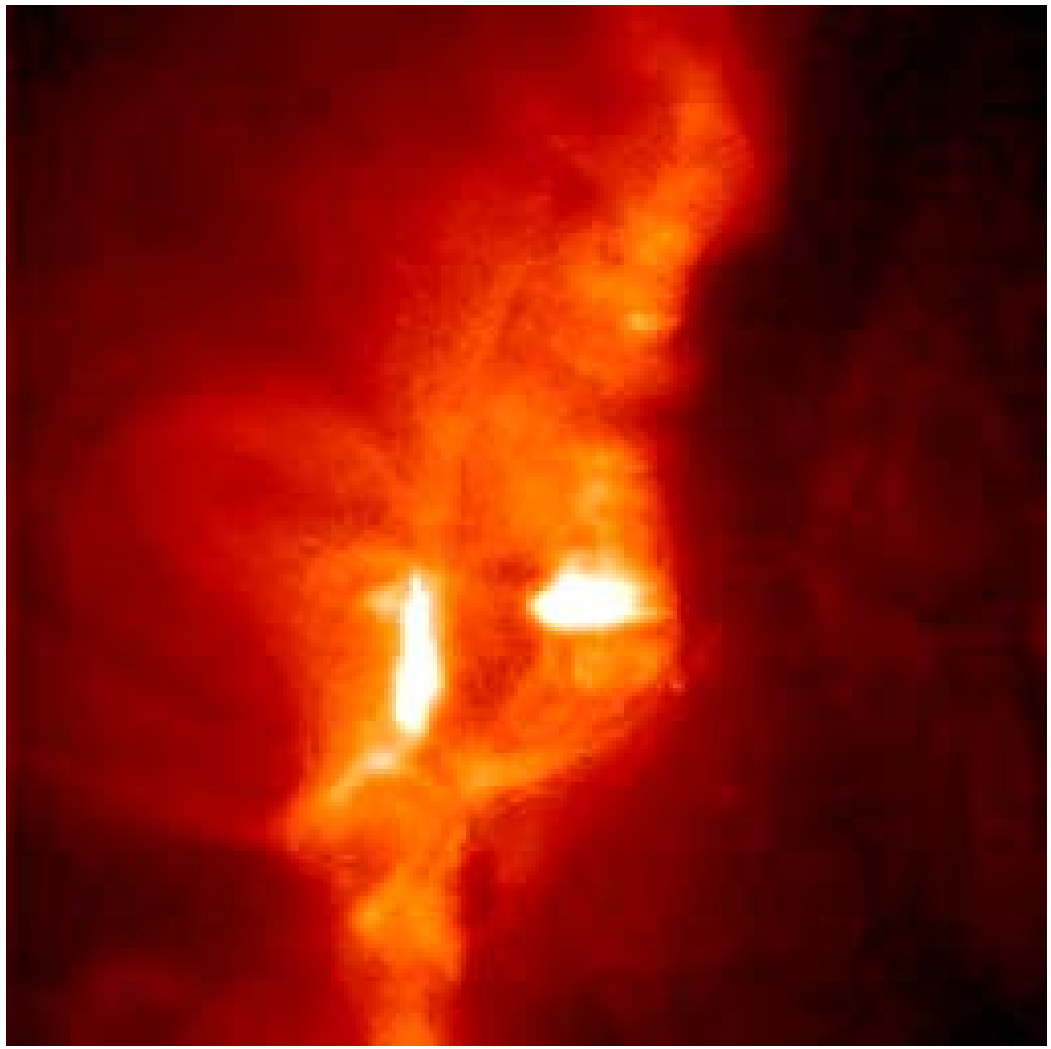
Global Restructuring Event

or

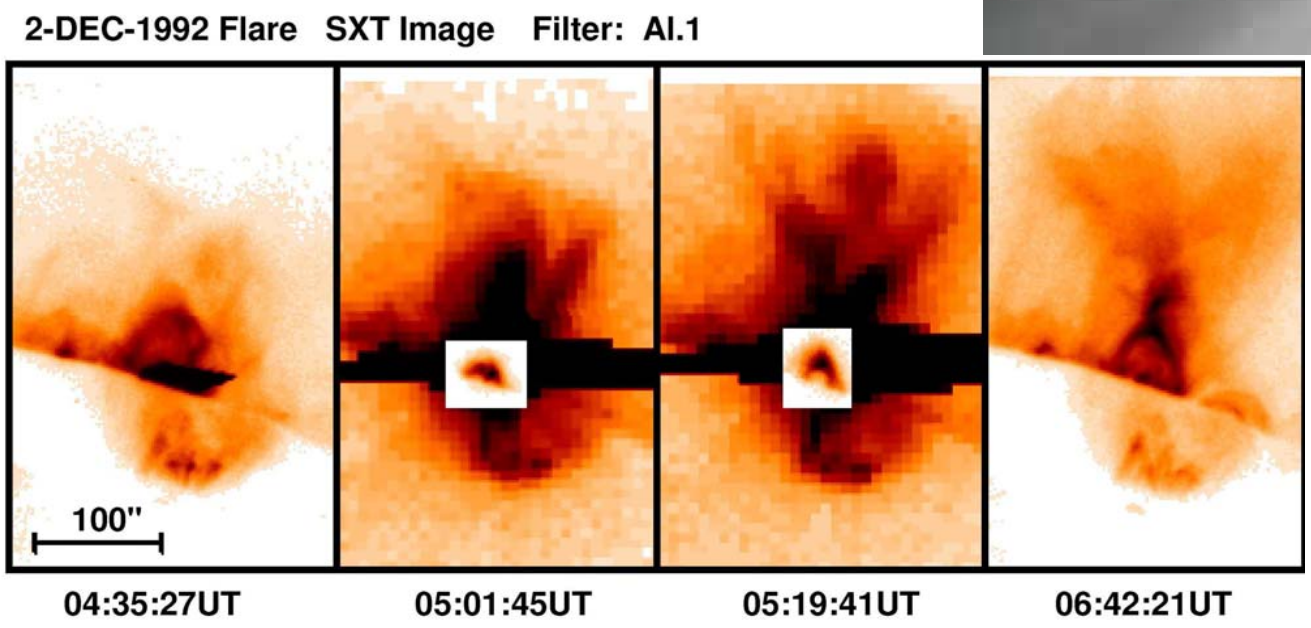
Giant Arcade Formation



LDE flares with a growing cusp structure.

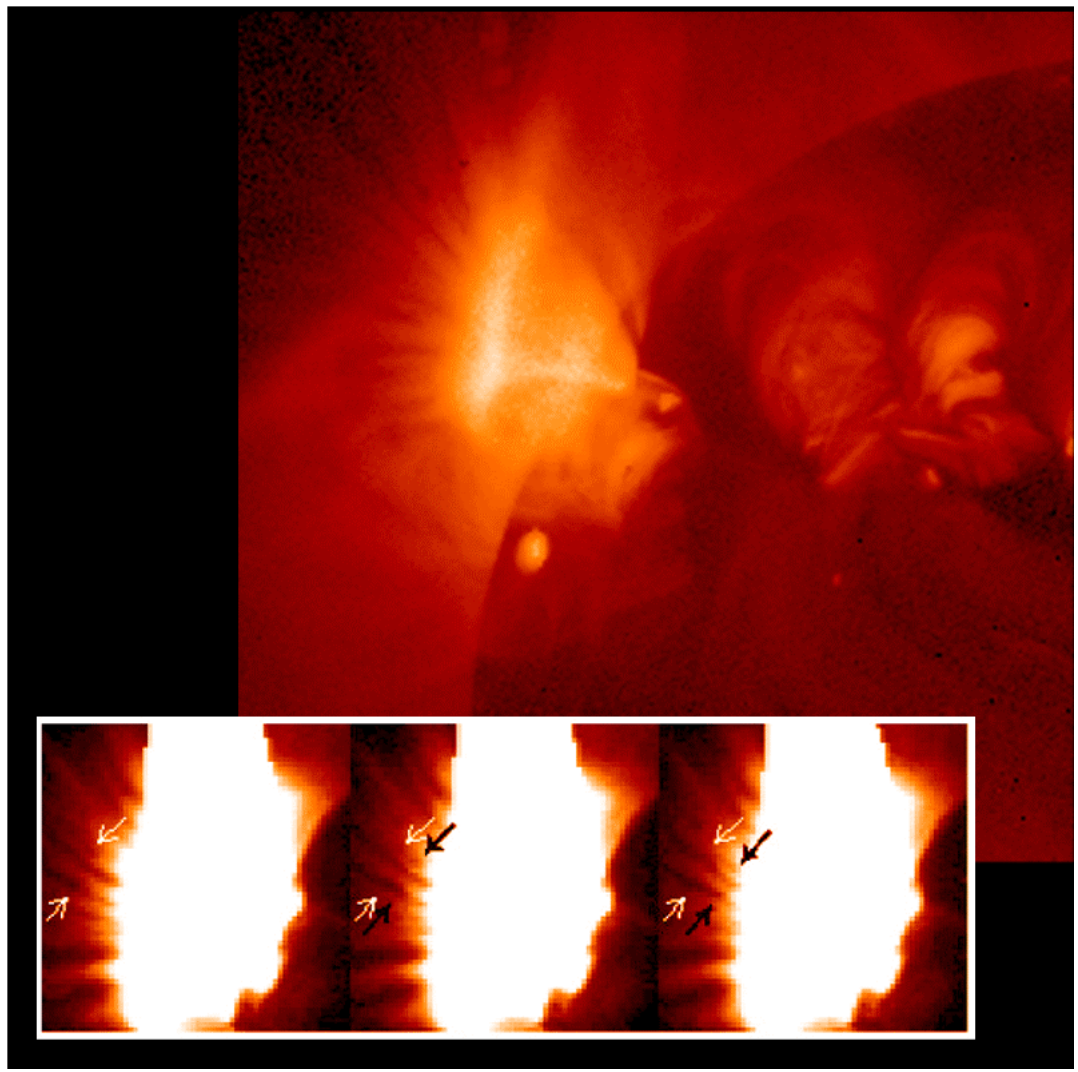


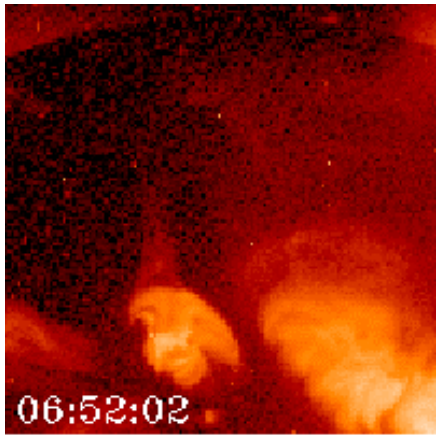
Flaring Loop and the Surroundings

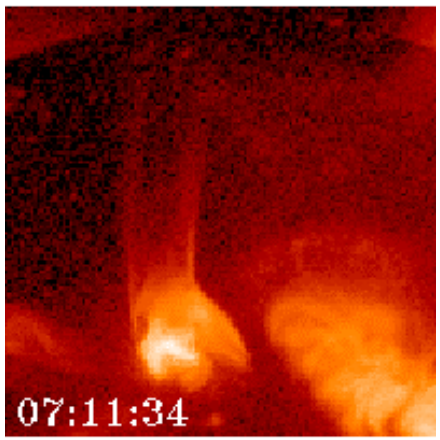


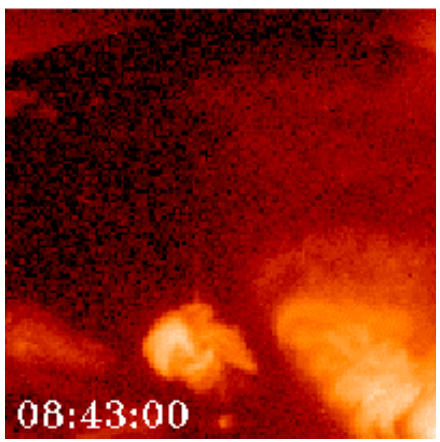
Downstreaming blobs above the arcade:

What's going on above the reconnection point ?



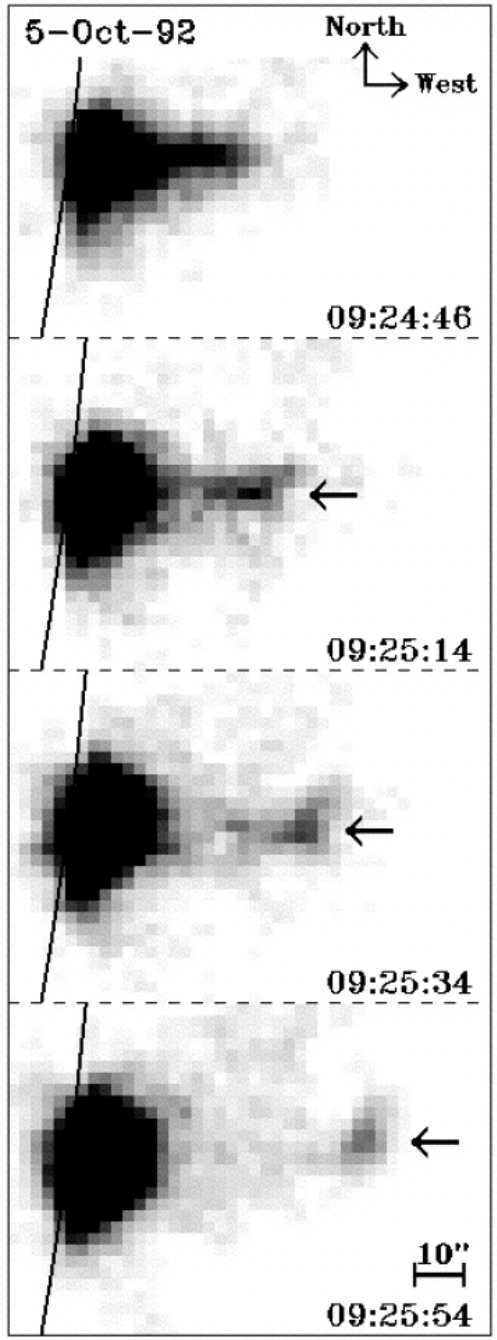






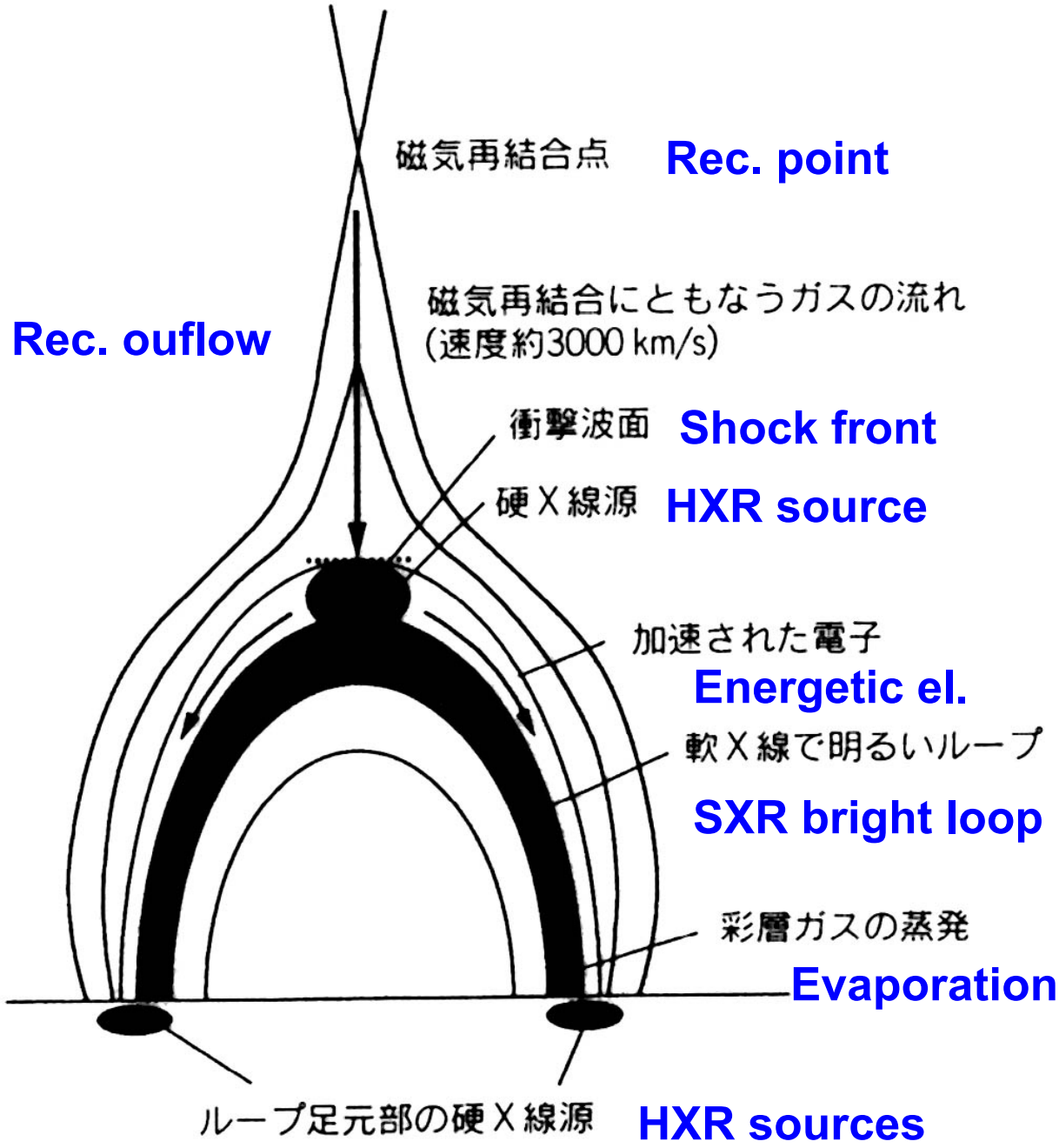
← X-ray jets

Plasmoid ejection in association with flares →



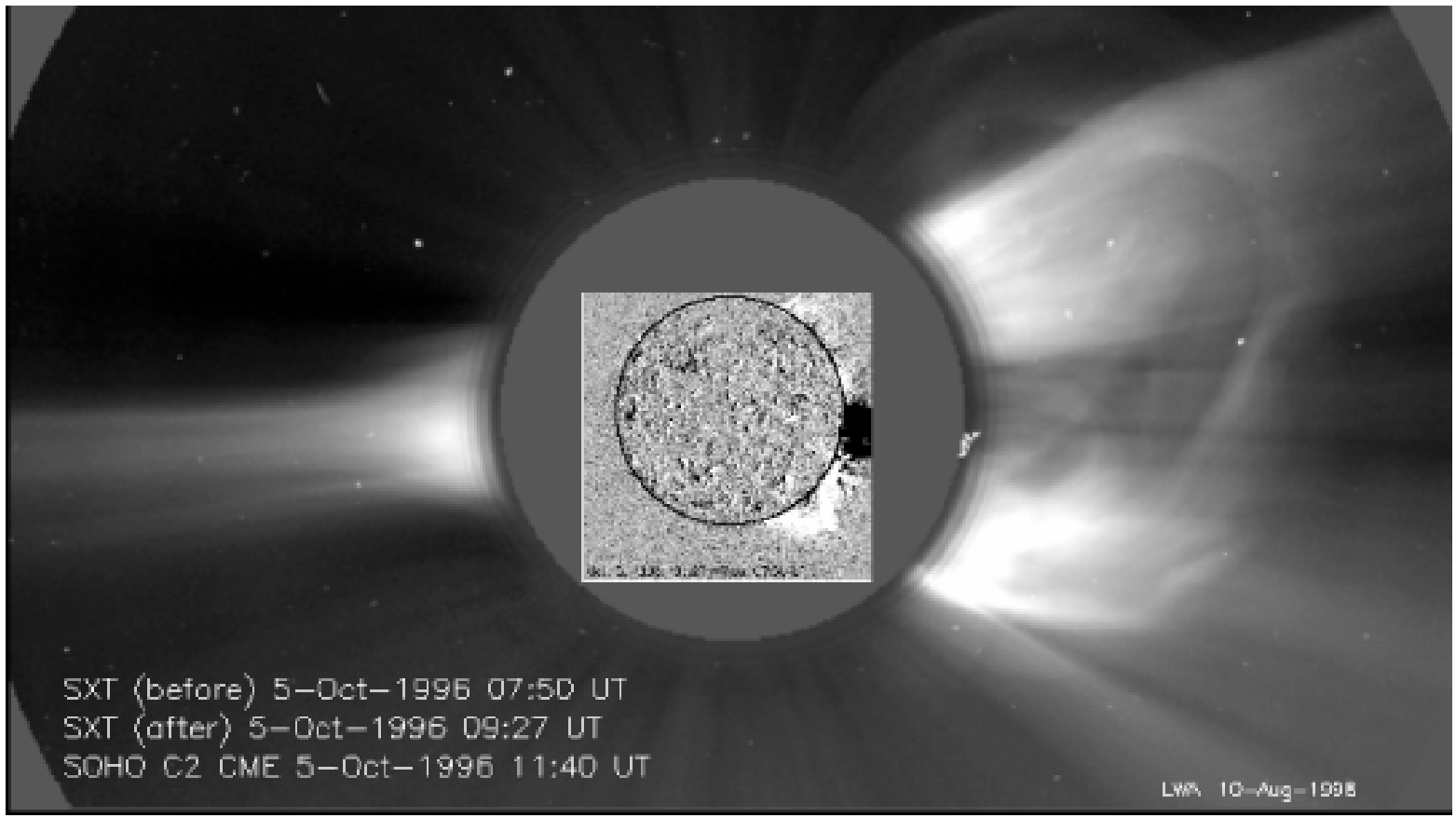
Yohkoh canonical view:

Magnetic reconnection

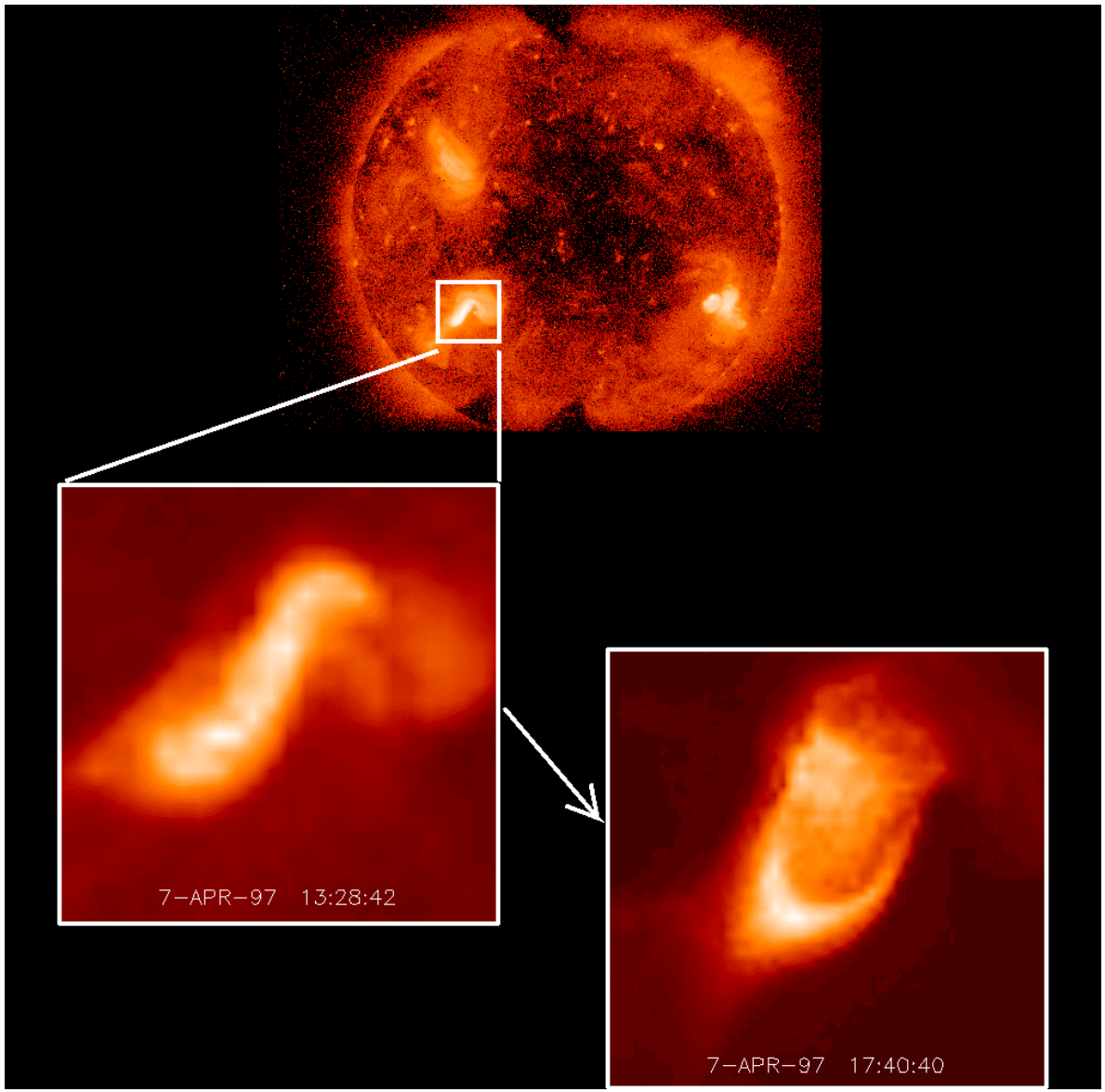


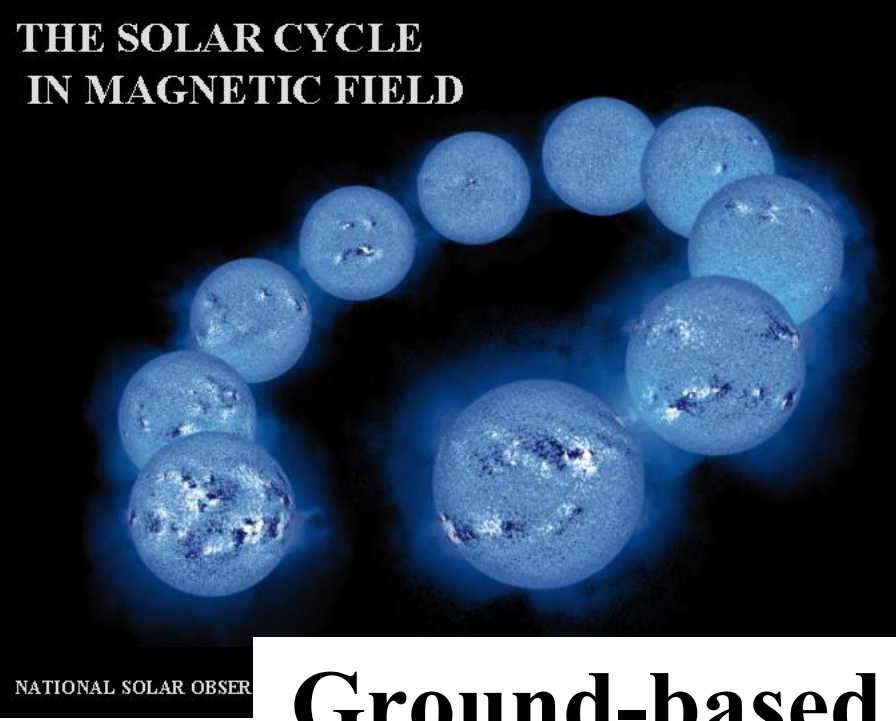
CME and Space Weather

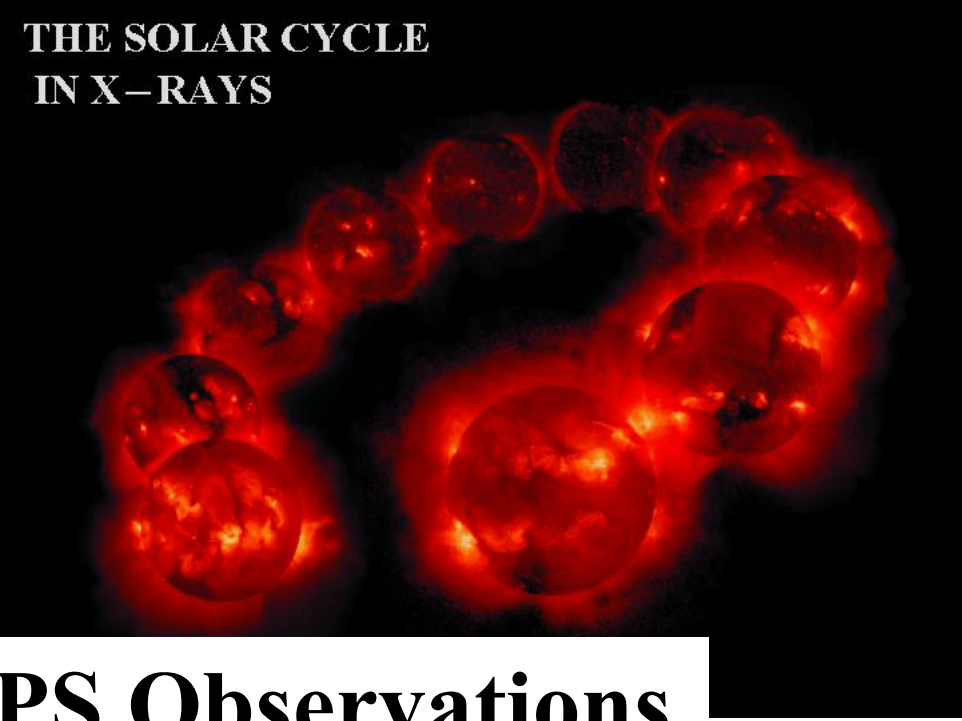
Coronal dimming (*Yohkoh*) *versus*
Coronal mass ejection (LASCO/SoHO)



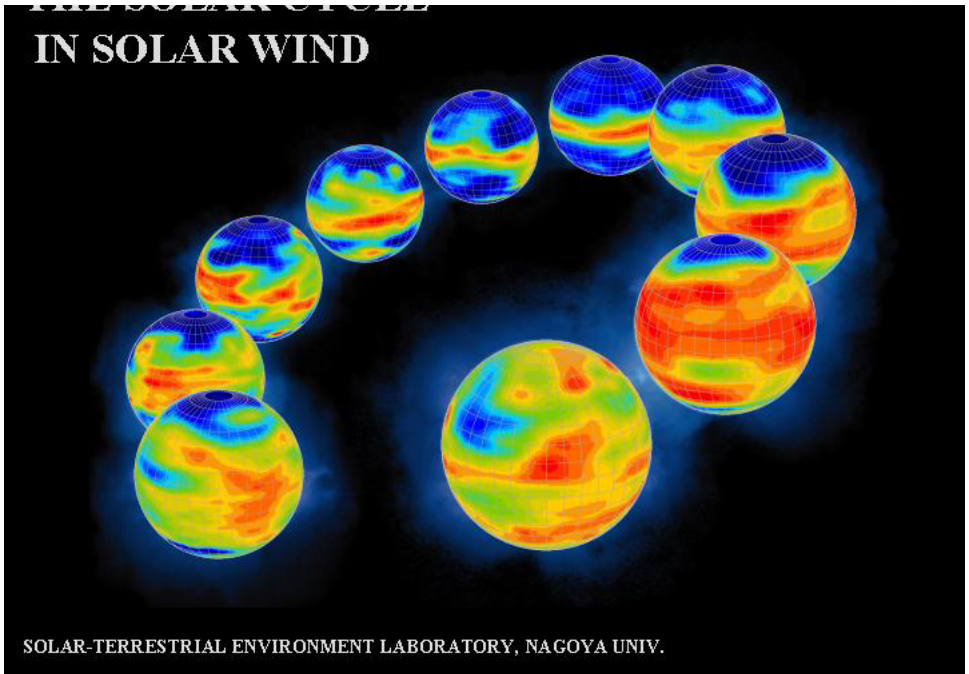
Sigmoid Structure and Eruption/CME







Ground-based IPS Observations



What's Next ?
From Yohkoh to ILWS / CAWSES

- Understanding Magnetic Connection
  from (sub)photosphere to corona
  atmospheric structures and dynamics
  coronal heating

  ➔ Solar-B; SDO; etc

- Understanding Solar Dynamo Mechanism

- Understanding Connected Sun – Earth System (Space Weather and Climate)

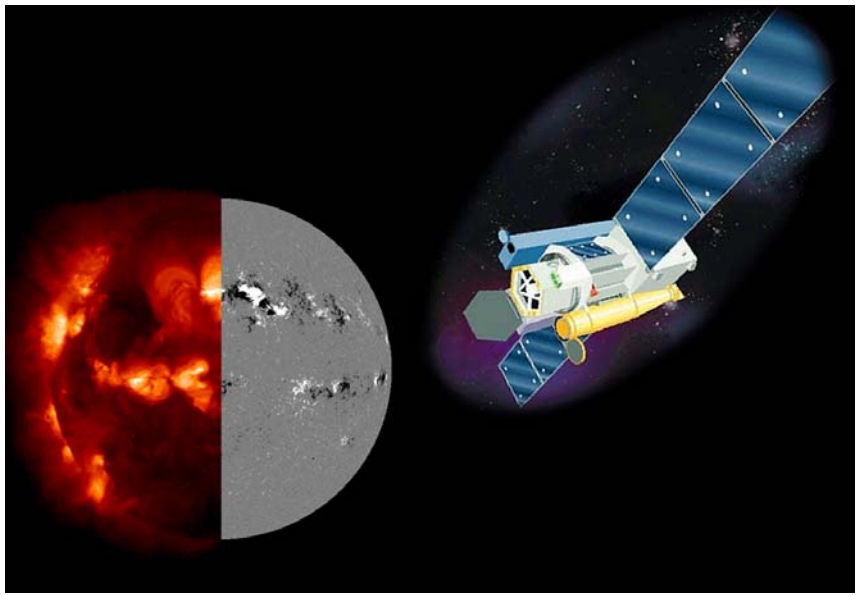
  ➔ STEREO; SDO; etc

ISAS / NASA / PPARC / ESA

SOLAR-B

Science

- Coronal heating
- Coronal structure / dynamics
- Elementary processes in Magnetic Reconnection



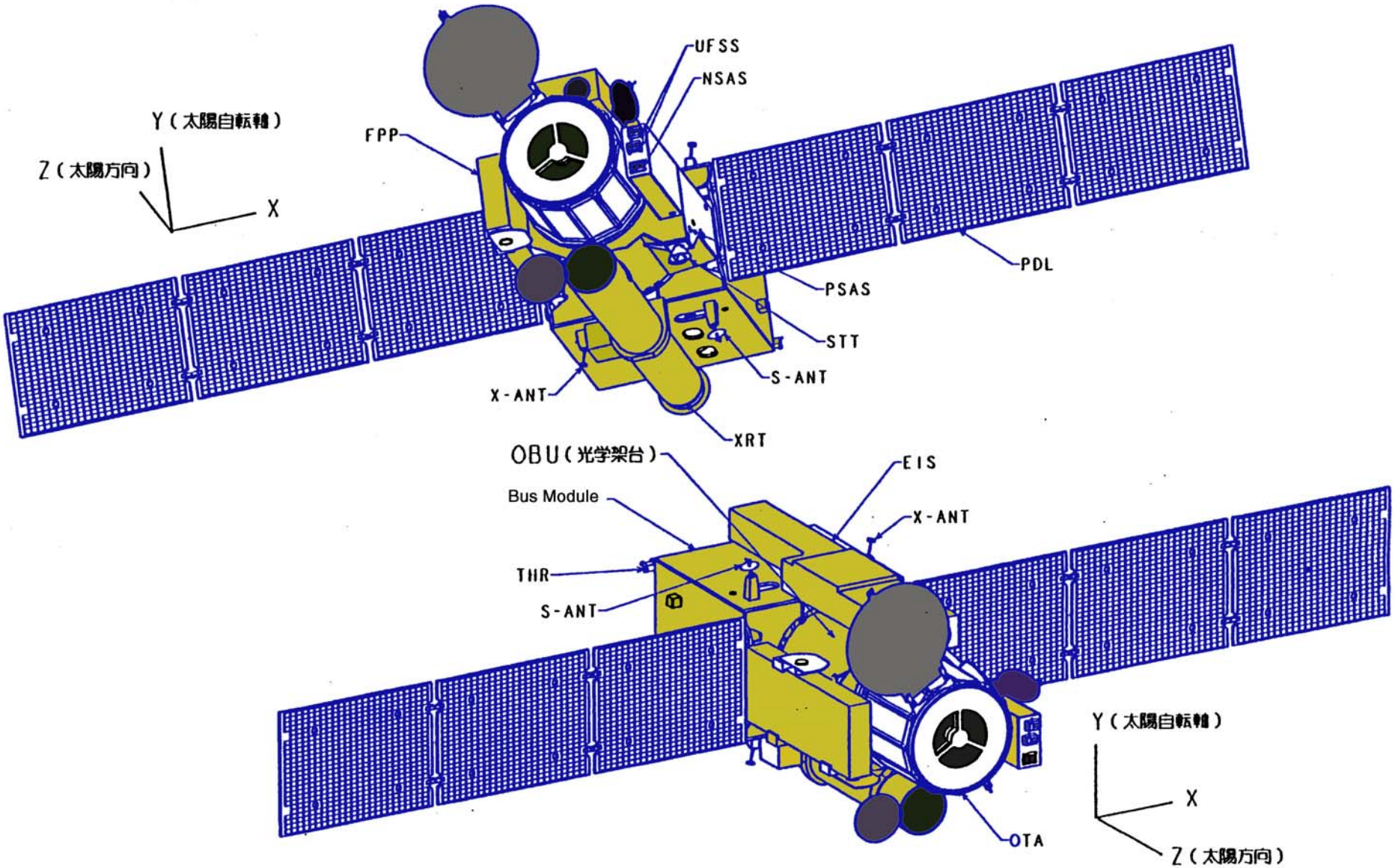
Launch Date:
Summer 2006
with ISAS M-V-7

Orbit:
Sun synchronous
altitude ~ 600 km

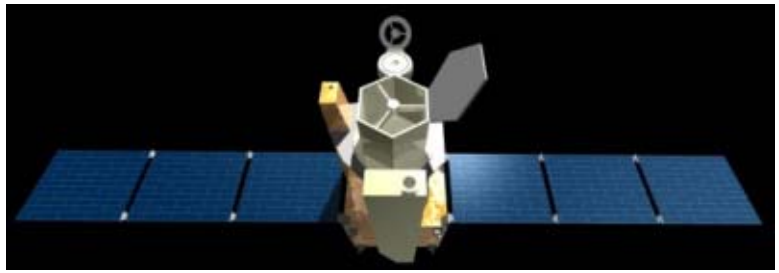
Weight: ~ 900 kg

Mission instruments

- Optical Telescope / Vector Magnetograph (SOT)
- X-ray Telescope (XRT)
- EUV Imaging Spectrometer (EIS)


Y（太陽自転軸）
Z（太陽方向）
X
UFSS
NSAS
FPP
PDL
PSAS
STT
S-ANT
X-ANT
XRT
OBU（光学架台）
Bus Module
EIS
X-ANT
THR
S-ANT
OTA
Y（太陽自転軸）
X
Z（太陽方向）

Key Elements with *Solar-B*



Instruments

- **Solar Optical Telescope (SOT)**

  Largest optical telescope ever to observe the Sun from space

  Diffraction-limited (0.2 – 0.3 arcsec) imaging in 388 – 668 nm

  Vector magnetic field measurement at the photosphere

- **X-Ray Telescope (XRT)**

  Highest angular resolution imaging at > 3 MK corona

  Wide temperature coverage from below 1 MK to above 10 MK

- **EUV Imaging Spectrometer (EIS)**

  Precise plasma diagnostics in the 17 – 21 nm & 25 – 29 nm ranges

Continuous observation without interruption for 8 months a year

Coordinated observation among the three telescopes

Structure of the solar atmosphere

SOLAR-B

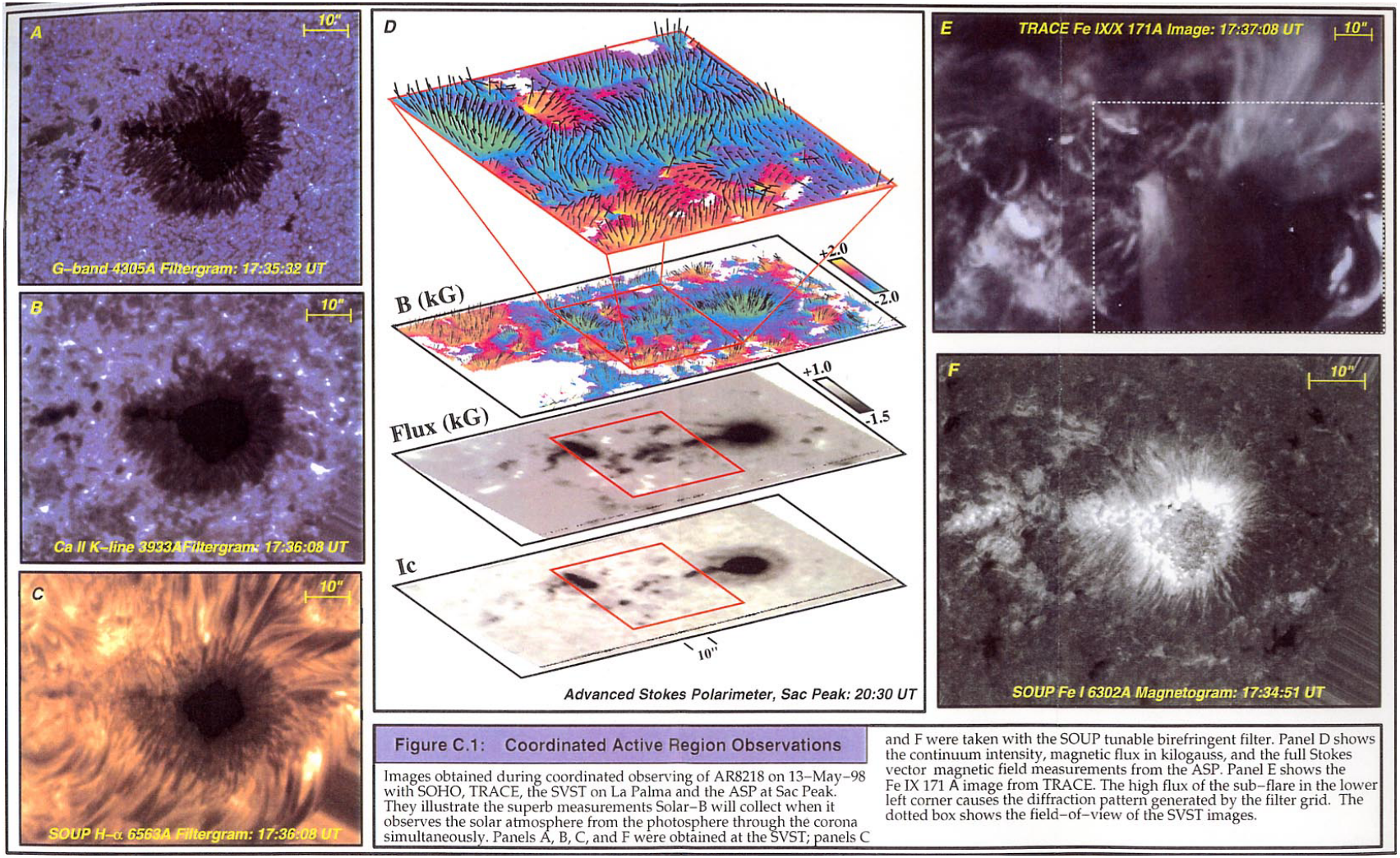


Figure C.1: Coordinated Active Region Observations

Images obtained during coordinated observing of AR8218 on 13–May–98 with SOHO, TRACE, the SVST on La Palma and the ASP at Sac Peak. They illustrate the superb measurements Solar–B will collect when it observes the solar atmosphere from the photosphere through the corona simultaneously. Panels A, B, C, and F were obtained at the SVST; panels C and F were taken with the SOUP tunable birefringent filter. Panel D shows the continuum intensity, magnetic flux in kilogauss, and the full Stokes vector magnetic field measurements from the ASP. Panel E shows the Fe IX 171 A image from TRACE. The high flux of the sub–flare in the lower left corner causes the diffraction pattern generated by the filter grid. The dotted box shows the field–of–view of the SVST images.

Lower atmosphere (Photosphere/Chromosphere) governs the dynamics of the upper atmosphere (Corona) via magnetic field lines

MTM Test (2002 May)

SOLAR-B